Abstract

In this work, an attempt is made to capture, from fundamentals, the influence of the Brazier effect (non-linearity between bending moment and curvature) in long and hollow composite spinning drive shafts. The shaft is modeled as a spinning tubular beam using a non-linear cross-sectional stiffness matrix, which captures the Brazier effect in an asymptotically correct manner. The weak formulation used here is the well-established version of the nonlinear dynamics of moving beams developed by Hodges. The critical speed of the thin-walled composite shaft is dependent amongst other parameters on the stacking sequence, the length-to-radius ratio (L/R), the thickness-to-radius ratio and the boundary conditions. The present analysis is verified by comparing the numerical results for specialized situation with those in the literature and good agreement is obtained. A special case of a drive shaft transmitting uniform torque and stator-rotor eccentricity is presented to demonstrate the Brazier effect in spinning composite drive shafts. Analysis shows that the Brazier effect (which earlier shaft theories fail to capture) becomes important at high speed spinning conditions for certain ply lay-ups.

The other independent part of the current work is an application of the Variational Asymptotic Method (VAM) in modeling the use of Active Fiber Composites (AFC) as smart materials in a thin walled composite shaft for both twist actuation and twist sensing. The study reveals an interesting coupling between the actuated twist and the electric field applied in radial direction as well as the coupling between the mechanical twist and voltage generated across infinitesimally thin electrode layers coated on the inner and outer surfaces of the shaft. This analysis has been able to predict the required material properties to account for the optimal design of active anisotropic shafts for the twist actuation and twist sensing problems. As expected, numerical study reveals that we need higher electric fields for the twist actuation of active shafts as compared

to active strips of similar size

Above analysis is further extended to analytical modeling of failure in active laminated drive shafts based on VAM The study reveals an interesting relation between failure torque and failure electric field applied in radial direction A numerical study is also conducted to investigate the effect of geometrical parameters The strength of the drive shaft is very sensitive to fiber orientation angle in the laminate It is found that applying an appropriate electric field can increase the strength of the drive shaft This final part of the current work is intended to enable the optimum design of active drive shaft against failure